National Aeronautics and Space Administration

Designing a Deep Space Bioregenarative System

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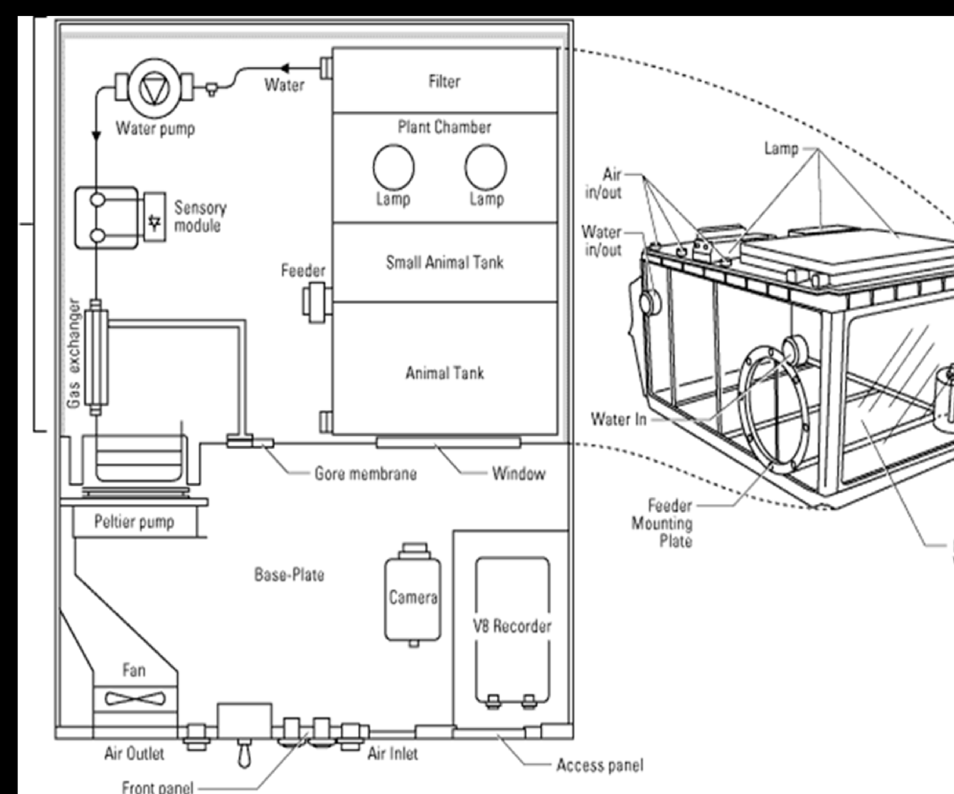
INTRODUCTION

Our purpose for assembling a closed system marine habitat that is self-sustaining is to study the impact of long duration space flight of living organisms. The project will involve an eventual mission of astronauts being able to feed themselves in deep space or while visiting Mars. This mission, when possible, will require us to have a bioregenerative system. The closed system marine habitat, that we are in the process of building, will house microbes, marine algae, certain types of aquatic plant species, invertebrates, and other types of marine organisms that will coexist in space for scientific research and analysis. Our system will consist of five subcomponents, minimum human intervention, invertebrates, nongravitropic plants, nitrogen fixating bacteria, and an electronic component that will be utilized to help maintain the system and collect data. The invertebrates utilized will help give scientist a better understanding of how microgravity, cosmic radiation, and different particles in the space environment have an effect on the organisms. This mission will precede future missions of sending vertebrates to deep space for a long duration of time.

DEVICE

A general component that we will send to space will have an aquarium for aquatic animals, a plant cultivator, filter with a nitrogen fixating bacteria, and an electronic component that will help regulate systems in the aquarium and attain data from the other components. Ultimately there will be minimal human intervention. Our system, unlike C.E.B.A.S., will contain saltwater species and will be sent into deep space. Our system will also attempt to maintain a culture that is similar to seawater temperature at 5° to 10° C. This will allow species to exist with a low energy output as opposed to utilizing room temperature which requires more energy for species to exist. In addition, this system will be utilized as a long duration experiment that scientist may analyze invertebrates and better prepare vertebrates for a similar mission.



POTENTIAL ORGANISMS

Sea Pen

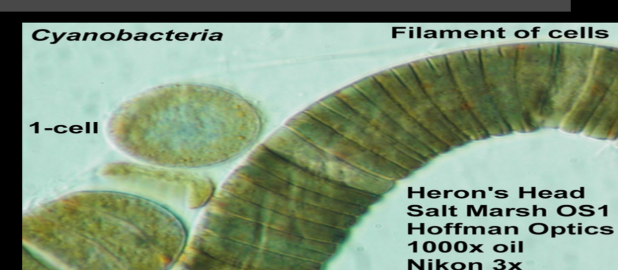
The Sea pen is a potential organism for our system. It lives in temperature ranges from 7.6° to 9.5° C. It also lives at that temperature at depths of 13m to 68m.

Plankton

Plankton live in all types of climates. They are photosynthetic organisms that take in CO2 to make food and release oxygen back into the environment. They are also food sources for many other organisms.

Green Algae

The green algae is a potential organism because it thrives is various climates, from extreme cold to extreme tropical environments. It can grow in freshwater or saltwater. It absorbs nitrates, CO2, and metal ions from the water. It is also found within the pH range of 8.1-8.4.



Cyanobacteria

Cyanobacteria is a nitrogen fixating bacteria that is found in either freshwater or seawater. It can survive in any type of environment. It is one of the oldest living organisms on the Earth. They also take in CO2 to carry on photosynthesis and release oxygen into the ocean.

FUTURE EXPERIMENTS

- Develop the actual closed ecosystem for invertebrates
- Test the closed ecosystem for accuracy in the lab
- Experimental systems with fully biological life support systems for Spacelab-Missions & space station (multi-generational experiments)
- Once the test with the invertebrates is completed and the data are evaluated, then a closed ecosystem with vertebrates would be designed.
- Influence of space radiation on germ cells & embryonic development of invertebrates
- Influence of µG on invertebrate mineralization intake
- Potential mutations on plant physiology and plankton
- Photosynthesis, ion uptake, biomass production

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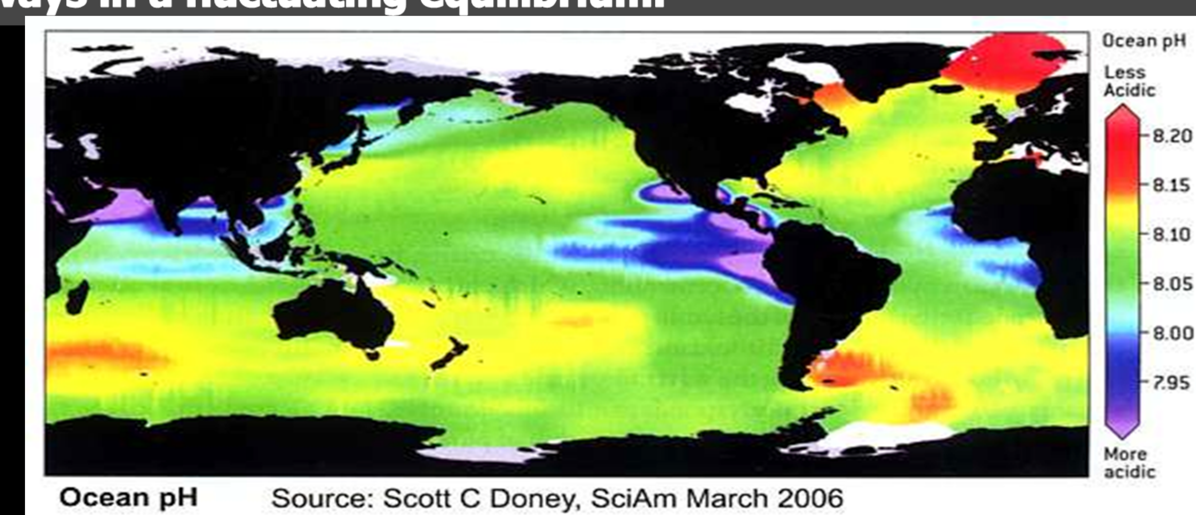
ACKNOWLEDGEMENTS

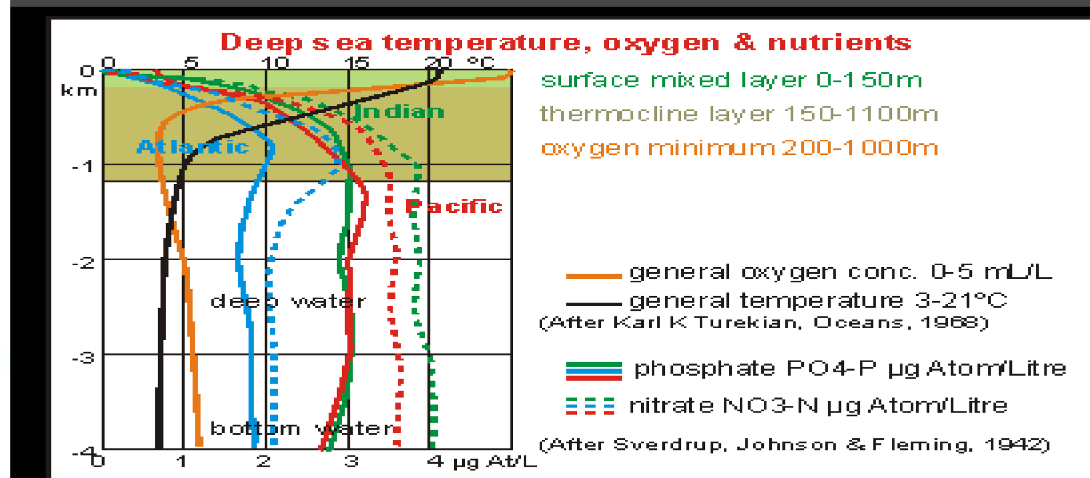
I would like to thank God for helping me with the ability to understand and attain the knowledge that I have learned through this summer. I would also like to thank the Star Program for giving me the opportunity to be here and to expand on my research skills. I would like to thank my mentors Richard Boyle, Anthony Intravenia and research partner Khrissaundra Journey for all their assistance on this project. And lastly, I would like to thank NASA Ames Research Center for allowing me the opportunity to participate in one of their many internships that are available to individuals who seek to expand on their scientific understanding of our universe.

MARINE HABITAT

The Salinity of Seawater is 3.5%. The density of fresh water is 1.00 (g/mL) but when salts are added, the density increases. The saltier the water is, the higher its the density. When water warms, it expands and becomes less dense. When water cools, it becomes denser. So it may be possible that the warm salty water remains on top of the cold, less salty water. The density of 35 PPT saline seawater at 15°C is about 1.0255. The pH of neutral water is 7.0. The pH of the ocean is around 8. This means that there are 20 times less hydrogen ions in seawater than there are in neutral water. It also means that there are 20 times more hydroxide ions in seawater than there are in neutral water. The buffering system of the ocean is the ocean carbon dioxide, water, and bicarbonate which is always in a fluctuating equilibrium.



This map shows that the ocean acidity around the world averages from 7.9 to 8.2. Along the coast, however, there are larger variations. The variations range from 7.3 inside deep estuaries to 8.6 in productive coastal plankton blooms and 9.5 in tide pools



This diagram shows how light penetrates no deeper than 150m for photosynthesis. Gas exchange with the atmosphere is near-perfect such that the oxygen concentration in the water is in equilibrium with the atmosphere.

My interest in our experiment focuses on the organism ability to coexist with each other within an ecosystem and their ability to survive and adapt to an environment with zero pressure. The invertebrate organisms that are presently being considered are species that live in the sea close to the 1 atmospheric pressure range (approximately 1m – 10m deep). Our initial concerns for the experiment are the organism ability to adjust to pressure and maintain life outside their natural environment. Although there are organisms in the deeper regions of the ocean that can adjust to lower pressure and survive, scientist have had a very difficult time maintaining their life outside of their natural sea environment for any extended period of time. Our mission success will depend on finding species that can live together for an extended period of time without annihilating each other. Example, if we utilize Brine shrimp and green algae there is a chance that the Brine Shrimp may consume all of the algae. An alga helps to absorb Nitrates and CO2 which is a crucial component in keeping the marine environment in a certain equilibrium. This equilibrium is important in maintaining a marine organism's ability to sustain life. The complexity of maintaining a partially closed system for space also involves finding non-gravitropic plants and teaching astronauts how to maintain these organisms. In addition, figuring out preventive measures for bacteria over proliferations, which are some of the many questions that must be answered.

So as we venture on a journey of a best fit scenario, more questions continue to arise. How do we maintain other key components involved in the organisms ability to sustain life over an extended period of time? This question involves which organisms we decide will be viable candidates for our experiment. These organisms will be integral parts of maintaining pH, O2 levels, CO2 levels, Nitrate levels, Phosphorus levels and other ionic components that are valuable parts of the marine ecosystem. Presently we our attempting to answer many of these questions through research and eventual experimentation. Our goal to have a self-sustaining bioregenarative system in deep space will take time, but can and will eventually happen through NASA ingenuity.

Our goal is to bring this project into the classroom. This will allow us to maintain collaboration with NASA centers, and to introduce hypothesis-driven scientific research.